

Analysing the transition of Jordan's electricity system: Underpinning transition pathways with mechanisms

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Abstract

Jordan's electricity system has and continues to experience considerable pressures for reform due to continuous increase of electricity demand combined with high dependency on imported fossil fuels and a partially subsidised electricity market. In this paper we use the transitions pathways to examine and analyse pressures on the regime in relation to plausible future developments of particular niches such as renewable energy technologies. Our analysis is methodologically distinct in that we explicitly identify mechanisms operating in the system and relate those to existing scenarios to assess future developments. Currently, we see future developments being sensitive to the actions of key regime actors.

1 Introduction

Jordan's electricity system has and continues to experience considerable pressures for reform. The gradual but continuous increase of electricity demand driven by internal and external factors combined with high dependency on imported fossil fuels, and a partially subsidised electricity market are creating political and financial pressures on key actors in the electricity system. At the same time, global developments such as decreasing prices for renewable energy technology and availability of innovative technologies for extracting and transporting fossil fuels provide new opportunities to mitigate the pressures. The future of Jordan's electricity system currently seems to be open to a variety of possible developments, including a stronger role of renewable energy, exploration of alternative sources of fossil fuels, and a stronger role of nuclear power.

In this paper, we examine and analyse the transformative pressures on the current conventional electricity system in Jordan in relation to plausible future developments of specific niches, in particular that of renewable energy technologies. We aim to make a qualified assessment of the main drivers of future developments of Jordan's electricity system, of the main branching points that decide between alternative possibilities, and of the most influential actors. Based on that we give policy recommendations to foster a transition to an electricity system based on renewable energy.

Achieving our objectives is challenging as the diverse set of factors that potentially influence future developments demands a broad overall perspective, while the ambition to assess drivers and to develop policy recommendations requires a detailed and mechanistic understanding of the system that relates particular dynamics to expected effects and specifies entities which are susceptible to interventions.

To achieve our objectives we develop and use an innovative combination of concepts and methods including the transitions pathways defined by Geels and Schot (2007), the PSM approach (Holtz, 2012) and scenario studies. The combination allows us to draw the overall picture, to zoom in to the most relevant details, to extrapolate developments into the future, and to make an assessment of their combined future effects with regards to overall transition dynamics. In addition to the insights gained

on the future developments of Jordan's electricity system, the paper therefore provides an exploration and test of innovative methods.

The remainder of the paper is structured as follows. First, we introduce our approach, including a brief description of the concepts and methods used. In a second step, we apply this approach to the case study of Jordan to learn more about the dynamics of the electricity system of this country, to describe a potential transformation pathway to a future electricity system based on renewable energy sources, and to formulate policy recommendations to support such a transition. We finally reflect the case of Jordan and the method used before we come to conclusions.

2 Concepts and methods

We apply a combination of concepts and methods to the case of Jordan to analyse the transition pathway of the electricity system in this Middle Eastern country. In particular we use: (1) the transition pathways concept, (2) the PSM approach, combined with (3) scenario studies of the MENA (Middle East and Northern Africa) region.

2.1 Transition pathways

Geels and Schot (2007) present a classification of transition pathways based on the multi-level perspective (MLP; Geels 2002, 2011; Smith et al. 2010). The MLP is a framework to describe the complex transition of an incumbent socio-technical system to a new emerging system using an integrated perspective. According to Geels (2002), a transition is the results of interactions between three different levels (see Figure 1): (1) the 'socio-technical landscape' which covers overarching developments such as climate change or an economic crisis that form an exogenous environment beyond the direct influence of regime and niche actors, (2) the incumbent 'socio-technical regime' which is at the centre of the analysis and reflects the dominant structure of policy-making, markets, industry, technology and cultures involved in meeting a societal need, and (3) the 'niche innovations', which are similar structures as regimes but are less mature and have emerged around radical technological or social innovations that constitute alternatives to the current functioning of the regime. Both, developments at the niche innovation level and the socio-technical landscape level create pressures on the socio-technical regime that might react with defensiveness or openness for the emerging system transition (Geels and Schot 2007).

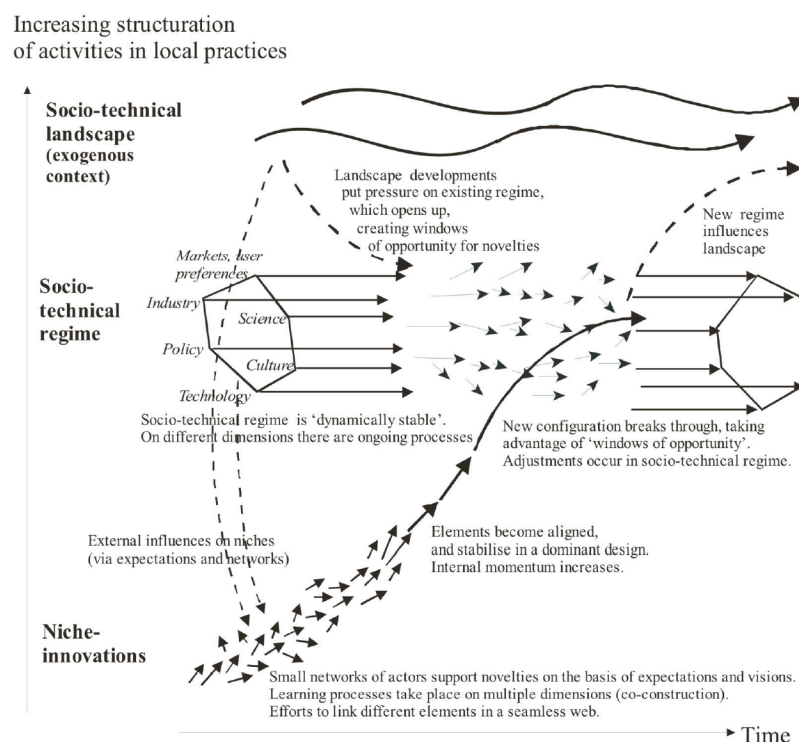


Figure 1 Illustration of the multi-level perspective (Source: Geels, 2002).

In this context, Geels and Schot (2007) distinguish four transition pathways: (1) Transformation path, (2) De-alignment and re-alignment path, (3) Technological substitution, and (4) Reconfiguration pathway. The transition pathways reflect insights gained through retrospective analyses on how transitions unfold in different cases, and what is important to distinguish different types of dynamics.

The difference between the dynamics of the pathways is explained by differences in (Geels and Schot 2007):

- 1) The type of pressure on the regime, which is distinguished between “specific shock”, “disruptive change” and “avalanche change”.
- 2) the timing of the interaction between levels: is a niche already mature enough to compete with the regime when the regime comes under pressure from the landscape or not?;
- 3) the nature of the interaction between levels: do niches and regime have a competitive or symbiotic relationship?

For our purpose, the transition pathways offer a framework to organize data of multiple kinds in a way that accommodates the multi-scalar, multi-sectoral and co-evolutionary characteristics of transitions.

In order to provide a basis for the description of the timing and nature of interaction of levels in the application to a case study (section 3), we will first describe the regime and the niche of renewable energies in broad terms. For both types of structures (regime and niches), various definitions exist, and the MLP has been criticised for the lack of a clear regime conceptualization (Holtz, Brugnach, und Pahl-Wostl 2008; Markard und Truffer 2008). For our purpose, we use the conceptualization of Geels (2004), who distinguishes three inter-related elements of regimes: 1) socio-technical systems, which are the relatively ‘tangible’ elements necessary for the functioning of the system and include inter alia infrastructure, technical artefacts, production facilities, consumption patterns; 2) actors who reproduce and maintain the system elements, e.g. policymakers, firms, consumers/users, NGOs; 3) rules and institutions which shape the actions, interpretations, and identities of social actors, including regulative, normative and cognitive rules.

Following Geels and Schot (2007) we assume that regime and niches are similar kinds of structures. We therefore use the same structure for a description of the renewables niche.

2.2 PSM approach

We make furthermore use of the PSM approach (Holtz 2012) to establish an explicit and transparent relation between particular empirical observations from a variety of backgrounds and their interpretation in terms of the MLP. The PSM approach includes the development of clear indicators for characteristics of and relations between MLP elements and the subsequent identification of mechanisms operating in the system. It is structured along three steps:

- 1) In a first step, a “phenomenon of interest” (the “P”) identifies a particular aspect of the overall transition that is in the focus of the further analysis. In our case, we focus on those characteristics that distinguish the different transition pathways according to Geels and Schot (2007): the timing and the nature of the interactions between levels.
- 2) In the next step we specify (“S”) these phenomena of interest and make them operational through defining sets of indicators.
- 3) In the last step we identify the mechanisms (“M”) which drive the developments of the indicators, i.e. those that determine the timing and nature of multi-level interactions. The identification of mechanisms adds a dynamic perspective that is relatable to scenario studies.

2.3 Scenario studies

We furthermore make use of scenarios to extrapolate current developments into the future. In this study, we do not develop particular scenarios ourselves, but we draw on existing one, where available. Scenarios exist in a great variety of types (Notten et al. 2003), among which descriptive scenarios are more useful for our purpose than normative ones. Brand and Blok (2015) have recently analysed different scenario studies in the MENA region to identify broad short-term trends, key uncertainties, and influencing factors.

2.4 Combination of methods

Figure 2 shows how we combine the concepts and methods described so far. Against the backdrop of the not yet further specified transition in the electricity sector in Jordan (upper left corner of Figure 2) we combine the transition pathways and the first two steps of the PSM approach to define a set of indicators for the timing and nature of interactions between levels (see Table 1, columns 1-3 in next section). Based on this specification, we use our knowledge of the case that we gained in multiple studies (DLR 2005, Fraunhofer ISE 2013, Greenpeace 2013, Knaack et al. 2014, DLR 2005, Fraunhofer ISE 2013, RCREEE 2015, etc.) to identify the mechanisms that determine the nature and timing of multi-level interactions (also Table 1, column 4). We then draw on existing scenario studies to extrapolate the developments of identified core dynamics into the future (Table 1, column 5). A qualitative assessment then leads to conclusions about the (future) timing of interactions between levels (e.g. pressure increases, niche matures), and whether the nature of interactions changes (e.g. further supportive regulations make the renewables niche more synergistic to the regime). Relating back to the transition pathways we identify multiple possible future developments, and develop a narrative that describes a specific pathway.

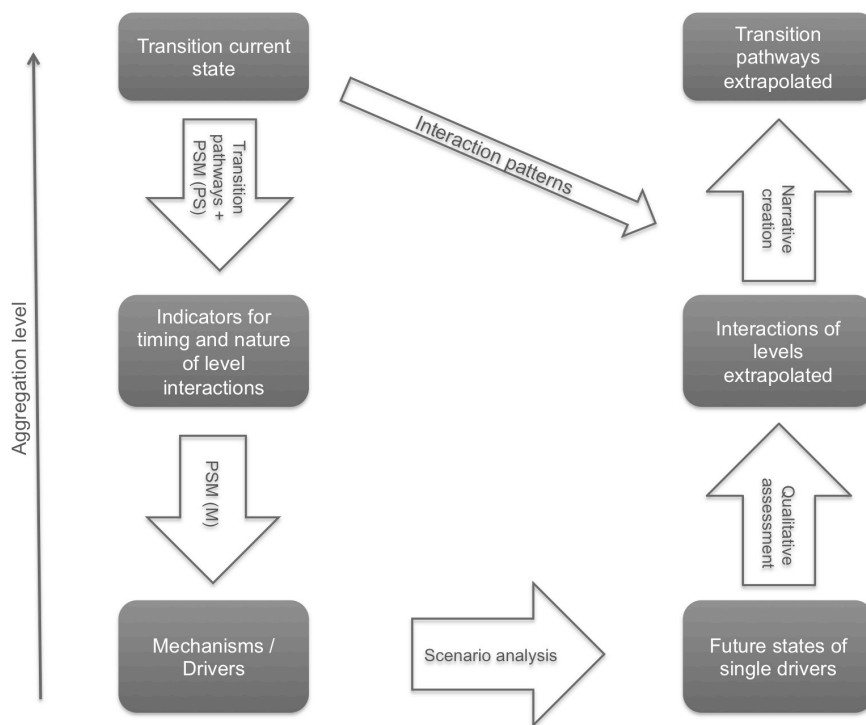


Figure 2: Combined methods

3 Application to the case of Jordan's electricity system

3.1 Description of regime and renewables niche

3.1.1 Regime

Jordan imports more than 97% of its needed energy, out of which the electricity sector consumes around 42%. Over long periods of time and until 2011, the main energy source for electricity production has been natural gas from Egypt and Syria. The political turmoils in Egypt and Syria, a series of pipeline attacks in Egypt and the war in Syria have interrupted the natural gas supply to Jordan which consequently had to be substituted. In 2013, the much more expensive Diesel has been the dominating type of fuel consumed in the electricity sector (39%), followed by Heavy Fuel (36%) and Natural Gas (25%). To mitigate the supply gap of natural gas, Jordan signed in 2014 an agreement with Israel which will provide natural gas for the next 15 years (NYT 2014). The main supplier for Heavy Fuel is Saudi Arabia.

Four main private companies are producing electricity in Jordan: The Central Electricity Generating Company (CEGCO), which is the largest power provider, the Samra Electric Power Company

(SEPCO), the Amman Power Generation Company (AES Jordan) and the Al-Qatraneh Power Generation Company. The transmission grid is constructed in a corridor from the North to the South, covering the more densely populated areas and connecting almost 100% of Jordan's population. The grid capacity is however low, what constitutes a challenge for installing additional power capacities (RCREEE 2015). Three companies are managing the distribution of power in the country: The Jordan Electricity Company (JEPCO), Irbid District Electricity Company (IDECO), and Electricity Distribution Company (EDCO). Jordan has a single buyer market, i.e., all generation companies have to sell the generated electricity to the state-owned National Electrical Power Company (NEPCO) based on power purchase agreements (PPA). As a consequence NEPCO is the connecting point for distribution companies and principal consumers. NEPCO is a leading actor in the electricity system of Jordan and fulfils furthermore the tasks of the system operator, the transmission network owner, the planner and developer of the power system. The company is also responsible for procuring the required fuel for power plant operation and for contracting new generation capacity to meet future demand. Electricity is sold to consumers based on a regulated tariff by the Energy and Mining Regulatory Commission (EMRC) who is acting as a regulator (Zarour 2015). As electricity costs currently do not reflect real prices, and consumers have become accustomed to cheap and stable electricity supply and tariffs, NEPCO has to carry the price differences what results in high financial losses of the company, and therefore the state. Due to these circumstances, the country is getting more and more under financial pressure (IMF 2015). The Ministry of Energy and Mineral Resources (MEMR) and the EMRC are in charge to govern the electricity system. Diversification of electricity supply along with energy security has high priority at the political agenda, as well as the reduction of energy dependency.

3.1.2 Renewables energy technology niche

Due to its geographical location, Jordan has high natural resources for solar and wind power and the economic potential of both can cover the estimated electricity demand of Jordan in 2050 more than a hundred times (DLR 2005). It has furthermore been argued that a transformation of the electricity system to 100% renewables is possible in Jordan (Greenpeace 2013). Wind energy projects in Jordan are already cost competitive with fossil fuel based power production (Zarour 2015). The installation of big power production facilities (> 5 MW) is licensed by EMRC under Law No 13 (2012). EMRC up to now issued one license for wind (117 MW) and 13 licenses for PV (in total 210 MW) projects. The former one belongs to the Tafila Wind Project, which is the largest wind project in the Middle East and is developed by an independent power producer (IPP), the Jordan Wind Project Company (JWPC) - a consortia out of InfraMed (50%), Masdar (31%) and EP Global Energy (19%) (Zarour 2015). The development of projects is driven by an improving investment environment, leading to a recent significant progress in attracting private investments to Jordan. A net-metering regulation provides an opportunity to develop small projects (< 5 MW) and to feed in generated power for a fixed tariff. This regulation resulted in a capacity of net-metering operated systems of private homes (PV) of 4.5 MW (261 meters) at the end of 2014. The current power market development included an increase of the electricity tariff of 7.5% in the beginning of 2015, which further increases the interest of private households to generate electricity with stable prices by themselves. The installed capacity therefore is expected to grow considerably to around 50 MW (1500 meters) until the end of 2015 (Zarour 2015). The low grid capacity is however challenging for installing additional RE power capacities (RCREEE 2015). Furthermore, Jordan's less-inhabited south-eastern part, which is especially suitable for solar power, is not part of the grid corridor from the North to the South yet (Zarour 2015). Grid expansion and reinforcement plans for RE projects exist ("green corridor"), but the costs have to be carried by NEPCO (Zarour 2015), which may results in a delay of the implementation due to NEPCO's financial situation.

3.2 Mechanisms driving the system

Based on this general outline of regime and niches, Table 1 more specifically analyses the mechanisms that drive the system. It is mainly structured according to the PSM steps. The first column names the phenomena of interest, which are subsequently specified further (column 2), operationalized through indicators (column 3), and finally the mechanisms that determine the further developments are identified (column 4). The scenarios that describe possible future developments are then outlined in column 5.

Table 1: Structuration of case knowledge according to PSM-approach and related scenarios for future developments

Phenomenon of interest	Specification(s)	Indicator(s)	Mechanisms	Scenarios for future developments
Pressure of landscape on regime: Specific shock + disruptive change	Shock: Discontinuation of supply with natural gas	Shortfall of supply from Egypt and Syria	Up to 2011, Jordan imported 96% of its energy, mainly natural gas from Egypt and also from Syria. The pipeline to Egypt had to be closed due to regional turbulence and repeated sabotage. The war in Syria impedes a stable supply.	Egypt is changing from a natural gas exporting to a natural gas importing country according to its rapidly increasing electricity demand and as natural gas fields have reached maturity or are in decline (BNP 2013). A natural gas supply from Egypt to Jordan therefore seems not realistic in the future. Nevertheless, Jordan is surrounded by several resource rich Middle Eastern countries that might provide fossil fuels for Jordan’s electricity system even after 2030. A terminal for liquid natural gas (LNG) has been opened in May 2015 (World Maritime News 2015), and an agreement with Israel has been made for natural gas supply for 15 years. A national supply of natural gas in the Risheh field is expected by 2018. Natural gas from the Risheh field would provide 100% of Jordan’s energy requirements until 2025 (Greenpeace 2013).
	Disruptive: supply with fossil fuels uncertain	Geopolitical situation of region	The turbulence in the region and war in Syria and Iraq undermine stable supply in many cases.	
		Supply Contracts		
	Shock: Sudden increase of demand to be met (refugees)	Increase in Peak Load and annual electricity demand	High number of refugees in consequence of the war in Syria	More than 620.000 Syrian refugees are living in Jordan right now (UNHCR 2015). Since four years the situation in Syria is uncertain and dangerous and peace negotiations have little success. A decrease of Syrian refugees in the near future is unlikely.
	Disruptive: Strong increase of electricity demand	Increase in Peak Load and annual electricity demand	Jordan is experiencing a rapid population growth.	An average growth rate of electricity demand of 7% is expected in the next ten years. According to estimates of NEPCO, the installed electricity capacity to meet demands will have to increase from 4,000 MW in 2014 to around 6,000 MW in 2023 and more than 8,000 MW in 2030 (Zarour 2015). Main drivers are the increasing demand for seawater desalination and population growth. Jordan’s population is expected to increase from 7.69 million people in 2015 to 9.35 million people in 2030 (UN 2012).
			Rising living standards imply increasing energy use.	
			Increasing need of electricity for sea-water desalination as a consequence of climate change, shrinking water resources and population growth.	
	Shock: Financial losses	NEPCO experiences high financial losses (around US\$ 1.7 billion in 2013 and 2014 together,	Jordan has a single buyer market. The electricity tariff to end consumers (ceiling tariff) is regulated by EMRC. A shortfall	The topic has become high priority at the political agenda. The government has increased electricity prices. The latest increase reflects only half of the

		Wilson 2015).	of the supply with natural gas from Syria and Egypt has lead to an increased use of much more expensive Diesel to maintain electricity production.	government's intention of an electricity price increase. Although an increase of 15% was required according to the government only an increase of 7.5% could finally be implemented due to public concerns (Wilson 2015). The national strategic plan for dealing with NEPCO's losses published by MEMR foresees a further adjustment of the electricity prices till 2017 (MEMR n.y.). The Jordanian government has already approved this price increase until 2017 (RCREEE 2015). The LNG-terminal, the national gas supply from the Rishah field and the contract with Israel will likely decrease prices for fossil fuels in the mid-term compared to the current situation.
		Tariffs for consumers had to be increased	To stop NEPCO's losses, EMRC can adjust tariffs for end consumers. By the beginning of 2015 the electricity tariffs have been increased by 7.5%. However, compared to the global level electricity prices are still low.	
Kind of interaction of niche and regime: mostly synergistic, partly competitive	Synergistic: National Energy Strategy in Jordan supports REs and supportive regulations have been implemented	Renewable Energy and Energy Efficiency Fund ¹	Political action: Jordan's Energy Strategy (2007-2020) main goals are to diversify the energy resources, to increase the share of local resources in the energy mix, to reduce the dependency on imported oil. The government is pursuing plans to achieve this.	<i>(The authors are not aware of political plans that go beyond the Energy Strategy)</i>
		Renewable energy policy targets		
		Liberalization of the power market for power producers		
		Feed-in/ceiling tariffs for renewable energies ²		
		Net-metering program ³		
		Competitive bidding ⁴		

¹ Financed by national and international institutions, the fund has a legal personality established under Law No. 13 (2012) and is financially and administratively independent. National and international companies can apply for support while setting up RE projects in Jordan. The fund provides subsidies to privately owned and operated RE facilities, it provides interest rate subsidies on commercial loans and supports the development of private investment in the sector. Further aspects are the guarantee to ease credit access and research and cooperation grants (IEA 2013). Projects in the pipeline are focused on innovation and R&D support and interest subsidy project for SMEs. Investments in larger renewable energy power infrastructures are currently not part of the fund.

² Regulatory directives based on a reference price list in form of a ceiling tariff have been issued by EMRC and permits direct proposals of projects. The feed-in tariff is focused on RE projects >5 MW. An additional incentive of 15% is paid on the listed prices if the installed RE system has its origin in Jordan.

³ The mentioned program allows any customer to sell the excess of RE generated power of own small-scale RE systems (<5 MW) to the electricity grid. RE systems that have their origin in Jordan receive in addition an incentive of 15% on the listed prices.

⁴ A public tender process is part of the development of large-scale RE power plants.

		Electric Power Wheeling applications ⁵		
		Self-generation applications ⁶		
		Plans for “green corridor”		
	Competitive: Renewables require investments in grid in times of scarce resources	Jordanien government has cancelled RE project due to concerns regarding grid stability and lack of funds to expand grid capacity (Rahim 2014)	The integration of fluctuating renewables constitutes challenges to the management of the electricity system. Jordan has to reinforce the grid to allow the integration of higher RE capacities in the future (RCREEE 2015).	The expansion and reinforcement of the grid is already under development as part of the so-called green corridor. However, this project is oriented to the already existing grid infrastructure and will not connect the south-eastern part of the country that is very promising for solar energy.
	Competitive: New actors start to compete with incumbents	Investors involved in renewables project pipeline are mainly foreign companies	Jordan’s electricity companys (on their own) do not have the required knowledge and funding to develop big RE projects. The government therefore aims to attract foreign investors.	Jordan companies have partnered up with foreign companies, and through inclusion in projects will develop own expertise with REs and may become more competitive for later bids. Through implementation of projects all involved actors gain experience and build up expertise.
	Competitive: different knowledge required	Majority of Jordan companies fails to meet quality criteria of the competitive bidding (Rahim 2014)	Technology specific knowledge required for building and operating power generation plants.	
		NEPCO has limited experience with effect of RE on the grid	Volatile renewables (wind, solar) are produced more decentralized and require additional flexibility measures to balance supply and demand.	
Timing of inter-actions: Regime under pressure and opening; niche not mature	Regime opening towards alternatives	Alternative sources of fossil fuel (LNG port, national gas field)	Recent developments have made the vulnerability of Jordan’s Energy system very visible. An important element of the Energy Strategy is diversification of energy sources and a stronger role of domestic energy sources.	It seems unlikely that the regime change will stop. However, the future development is contingent. For example, public resistance against nuclear power plans may hamper the implementation. Several concerns have already been raised due to Jordan’s lack of nuclear expertise, a lack of cooling water, grid weaknesses and seismic concerns. The selected reactor type is furthermore not proven yet (Greenpeace 2013).
		Nuclear option explored (implementation of a first 1 GW nuclear power plant is estimated for 2022, contracts have been signed)		
		Regime opens up to renewables (see above)		
	Status of renewables	Status of learning processes:	Jordan profits from developments on the	The costs of solar technologies, e.g., CSP, are

⁵ Allow the customer to install RE power applications in different Jordanian locations, to feed-in the generated renewable electricity into the grid and to transfer it to the location of consumption. A wheeling charge from 4.5 fils/kWh to 11.5 fils/kWh depending on the direct connection with the transmission and/or distribution grid is accounted for generated electricity.

⁶ RE applications can be installed for self-consumption of generated electricity.

	niche: unrealized potential	technologies are available. Wind power is competitive and PV has also already achieved grid parity for some electricity customers (Greenpeace 2013).	global market that included strong price reductions for wind and solar.	expected to further decrease in future but with a slower rate compared to past years. Also costs for wind power (onshore) are expected to further decrease although to a lesser extent (Fraunhofer ISE 2013).
		Support from powerful actors is contingent	There is a strong commitment of Jordan's government for RE as core element of a future energy system, and MEMR supports renewables through regulations. There is however no clear distinction of responsibilities for renewable energy sources and fossil fuels, and a dedicated renewable energy agency does not exist. Little experience with RE sources at NEPCO, who is responsible for planning and developing the power system and even to contract new generation capacity to address future demand, might constitute barriers for an ambitious development of renewables.	According to visions of powerful actors, RE will play an important role in Jordan's future energy system. However, the extent and the role of alternatives such as fossil fuels and nuclear may be contingent on political will and politics in MEMR and NEPCO.
		Market share is currently low (but growing)	Projects issued through competitive bidding ⁷	Jordan aims to cover 10% of the primary energy consumption in 2020 by renewable energies. NEPCO expects a RE share of 36% of the total electricity capacity connected to the grid in 2017 (solar: 710 MW representing 21%; wind: 516 MW representing 15%). For the year 2020 a RE share of 45% is expected (solar: 1,110 MW representing 28%; wind: 716 MW representing 17%). (Based on Zarour 2015).
			Household scale projects ⁸	

⁷ There is a project pipeline of 17 PV projects with a capacity of around 475 MW and 6 wind projects of around 395 MW. In addition, the 117 MW Tafila Wind Project is already under construction (Zarour 2015).

⁸ In 2015, the following projects have been approved to be implemented (Hamzeh 2015):

- Household PV pilot project for North Jordan (est. 20,000 PV private home systems in 2018)
- Household solar water heater project (est. 60,000 solar water heaters in 2018)
- Energy efficient lighting projects delivered by electric utilities (est. 200,000 LED lamps in 2018).

Distribution of LED bulbs in refugee camps

4 Integration and results

4.1 Extrapolation of interaction between levels

According to the analysis shown in Table 1, the *pressure of the landscape on Jordan's electricity regime* is severe and will maintain high in the future due to an expected doubling of demand in the next 15 years. The current regional crises have shaken the incumbent regime and have put it under severe pressure that in particular manifests in massive financial losses. The recent agreement with Israel, the envisioned national supply of natural gas in the Rishah field and the recently opened terminal for LNG may mitigate some pressures and may provide some financial “breathing space” in the next 15 years, but whether sufficient amount of (cheap) natural gas can be provided from neighbouring countries also in the longer term is uncertain, yet. It seems apparent that Jordan would benefit from a changed future electricity system based on different kinds of power sources, ideally one that is more robust to external shocks and that reduces energy dependency.

The *interaction between the regime and the renewables niche* is mostly synergistic, but partly also competitive. REs are part of strategic energy plans, and EMRC licenses RE project accordingly. The government has started to open the electricity market for IPPs who develop RE projects, and the implementation of REs is supported by various regulations, including feed-in tariffs and a net-metering program. However, the main regime actors, including the power producers but also the regulators, still have a lack of experience with REs. It can even be recognized that the state-owned company NEPCO is reluctant to support a rapid increasing RE share due to its little experience with fluctuating RE sources and concerns regarding their effects on the stability of the electricity system (Zarour 2015), what even lead to cancellation of RE projects. These concerns and reservations can be expected to become less in the future, as all involved actors gain experience through projects currently implemented and planned. The grid capacity and stability are however major technical bottlenecks for a quick extension of RE capacity, and the extension and reinforcement of the grid requires funding that is currently very scarce.

Regarding the *timing of the interaction*, as outlined, the regime opens up to alternatives, but the RE niche is not mature yet, and its future growth is almost completely under control of regime actors. The market share of the renewables niche is up to now small, but growing rapidly. Jordan made significant progress in 2014 to attract private RE investments that may speed up the diversification of niche actors in the future and provide RE related experience, thereby reducing the knowledge gaps of regime actors. Another field where the niche grows significantly is the development of small-scale projects on household level which are supported by the net-metering program. However, despite of recent and expected strong increases, these contribute a small part to overall electricity production only, and the future growth of that segment depends on the net-metering program and the electricity prices, both of which are under control of governmental actors.

The *competing niche* of nuclear power is also gaining some momentum, what is evidenced by the planned nuclear power plant. Its prospects are however very unclear, as the selected reactor type is facing technical challenges and Jordan has a lack of experience with nuclear energy. Grid weaknesses, seismic concerns and a lack of cooling water are further arguments against the development of nuclear power. In any case, the installation of nuclear power capacity is a time intensive process and therefore the nuclear option is not suitable to address the current immediate pressures on the regime.

Although it includes elements of a specific shock type of pressure which are absent in the archetypical description, the situation sketched here closely resembles the conditions for a *transformation pathway* of Geels and Schot (2007): the regime is under strong pressure while the niche is not yet mature and the relationship between niche and regime is mostly synergistic. In historical cases that underpin the ideal type of a transformation pathway the regime has changed gradually through incorporation of elements of (the) niche(s). Indeed, at the current state it seems plausible that also in the Jordan case the main regime *actors*, MEMR, NEPCO, EMRC and the existing power producers will firmly stay in place, although additional actors, namely further IPPs and households will enter the picture. Regarding the *socio-technical system*, mainly the production system is under pressure for change, and this change has already started through the implementation of RE projects, including a new decentralized component of household level production, but also through searches for alternative sources of fossil

fuels and plans for a nuclear power plant. The increase in power demand and the changes in the production system imply a need for grid expansion and reinforcement, whereas especially the incorporation of large shares of volatile renewables will constitute considerable challenges for grid reinforcement and requires additional balancing measures such as storage and demand side management. The *rules and institutions* have already and might further change the most, including a whole new set of regulations that facilitate the inclusion of IPPs, the regulation of volatile REs, and the abandoning of established use cultures, namely the availability of cheap and stable electricity. Still, fundamental institutions state shape the structure of the system, in particular the single-buyer market, seem to be undisputed.

4.2 Potential transformation pathway

The renewables niche is not yet mature enough to replace the fossil fuels centred regime within the next 10-15 years in large parts, as learning as well as building up power production and grid capacity is required. Based on our analysis, a potential transformation pathway to an electricity system heavily based on renewables could look like this: the current financial crisis allows NEPCO to increase consumer electricity prices. This measure and the substitution of costly Diesel through LNG from the newly opened terminal and the natural gas supplied by Israel support the mitigation of financial pressures of the Jordan state in the short term. The development of the Risheh field from 2018 onwards provides the potential for a further alleviation of the financial situation, and in combination with increased electricity prices reflecting real costs may provide the financial means to repay previous losses and to develop the grid capacity and balancing measures that are required for the future renewables based electricity system. The extension of the RE project pipeline can then be implemented in accordance with grid capacity and growing knowledge and experience. The increased electricity prices thereby increase the incentives for private investors to engage in IPPs and to apply for RE projects, and might create a momentum to attract more investments for additional projects. At the same time, the increased electricity prices and the net-metering program might stimulate the growth of PV capacity on households level, thereby contributing to a future energy system that is more decentralized and more robust against external shocks. Due to a quick and strong extension of renewables based electricity generation the costly and non-sustainable plans for the nuclear power plant become dispensable.

The feasibility of the outlined pathway depends on several issues that require additional, quantitative studies to test and underpin the sketched ideas: the financial situation including the gains and costs from increases in consumer electricity prices, the LNG terminal, the exploitation of the Risheh field, investments in grid infrastructure, etc. requires a calculation of the financial balances. Furthermore, a more precise picture of the development of production and grid capacities as well as electricity needs would be required to assess whether the RE project pipeline is sufficient to address the existing and growing gap in production capacity. These aspects would require model based studies (Holtz et al. 2015; Trutnevyte et al. 2015) to develop a more precise picture.

Due to the single-buyer model market forces are repressed, and governmental actors have almost full control over the process. The sketched developments are therefore highly contingent on politics within the MEMR and NEPCO, and the political will to steer developments (consumer electricity prices, grid expansion, RE regulations and project licenses, net-metering program) in a way that supports a transition to renewable energies.

Of concern is the shift of financial pressures from the state to consumers, whose social acceptability has to be considered and which might cause public concerns and resistance that should be addressed, although the overall financial situation of Jordan may leave little room to reduce the financial burden of consumers. The reasoning and transformation actions have to be communicated in an appropriate way with the society to gain social acceptance and support. Otherwise, windows of opportunities might be opened for rivaling niches that could setback the integration of RE in the electricity system. Particularly the installation of a large-scale nuclear power plant that requires large investments and provides unflexible base load capacity would create path dependency and limit the extension of renewable energy.

4.3 Policy recommendations

Based on our analysis and the outlined transformation pathway, we make the following six broad recommendations to support a transition to renewable electricity generation in Jordan:

- (1) Strong political commitment: Formulation of a precise long-term project pipeline and ensuring the implementation that will result in more experience with RE. This includes also pilot projects of innovative technologies, e.g. CSP, that address several challenges like power generation and seawater desalination.
- (2) Grid infrastructure: Expansion and reinforcement of the grid infrastructure to guarantee grid capacity and facilitate a rapid increase in RE installations (including balancing measures). Extension of the power grid to regions that are particularly qualified for RE production in the future.
- (3) Regulatory framework: Create a strong regulatory framework for RE and further liberalize the power market to attract private investments. This includes the increase of electricity prices in a socially acceptable way to reduce the financial losses of NEPCO .
- (4) Flexibility of power system: Don't install high shares of inflexible base load capacity (e.g., nuclear power) in order to prevent path-dependency.
- (5) Independent RE agency: Implement an independent RE agency that is responsible for the development of RE projects to pool experience and prevent a conflict of interest.
- (6) Social acceptance: Transformation strategies have to be communicated in a transparent and appropriate way to the society to gain social acceptance and support.

5 Discussion

5.1 Reflection on Jordan case

Our analysis of the transformation of Jordan's electricity system has shown that the regime is under strong pressure, but the direction of the transition is still open and steering towards a more sustainable future electricity system based on REs requires supporting actions based on a mechanistic understanding of drivers and barriers as well as an assessment of likely future developments. The RE niche is not mature yet, but features high potentials to become the backbone of a future electricity system. Although the implementation of a RE-based system would require learning and a balanced approach of capacity and grid extension, the feasibility and cost-effectiveness of such a system seems evident based on our knowledge. In contrast, the availability of cheap natural gas cannot be guaranteed in the long term. Also, the prospects of the nuclear option are uncertain, and this option also does not provide means to alleviate current immediate pressures. Consequently, in our view, a commitment to a RE-based future electricity system seems to be the most beneficial option from the viewpoints of sustainability, energy security, and cost-efficiency.

Incumbent electricity regime actors such as MEMR and NEPCO will have to play a major role in a transition to a RE-based electricity system. They are not expected to counteract such a transition as they likely will not lose power during that process. Furthermore, the current crisis has made these actors highly aware of the limitations and risks of an electricity system based on imported fossil fuels. However, strong barriers for the implementation of renewables have to be overcome, mainly a lack of experience of regime stakeholders with REs, and the required grid extension and reinforcement which entails expenses in times of very limited financial resources.

5.2 Reflection on method

The used combination of transformation pathways, PSM approach, scenario studies, qualitative assessment and narrative creation allowed us to start from the broad picture, to identify relevant aspects to focus the analysis, and to create informed assessments of potential future developments. We consider this combination therefore promising to contribute to a refined method toolbox of transition studies. Still, there are several qualifications to be made and there is room for further development. The decomposition of the broad picture into indicators and mechanisms required a certain amount of „ad hoc“ decisions on specifications of the phenomena of interest (Table 1, columns 2-3) based on our case-specific knowledge, what reflects the general absence of metrics and indicators to measure transitions in the transitions literature. The three indicators for the status of the niche (status of learning processes, support from powerful actors, market share) which we used and which were taken from Geels and Schot (2007) provide a notable exception. The development of metrics and indicators

for other phenomena of interest would support the rigour of the applied method combination. In turn, studies such as the one presented can stimulate and contribute to the development of such metrics and indicators.

The qualitative assessment we have used to compose potential overall future developments from the underlying specific scenarios allowed us to draw a general storyline that might serve as inspiration and guiding vision. In order to come to more robust conclusions and plans, additional (quantitative) studies of particular aspects of the transition storyline(s) would be required.

6 Conclusions

We have used a combination of concepts and methods including the transformation pathways, the PSM approach, scenario studies, qualitative assessment and narrative creation to analyse the transition of the electricity system in Jordan. The chosen approach thereby allowed us to start from the broad picture, to identify relevant aspects to focus the analysis, and to create informed assessments of potential future developments. Based on our experiences made in this application, we consider the used combination of methods promising to contribute to transition studies.

We found that in our case study the main drivers of the transition are the strongly increasing demand for electricity in Jordan, the recently interrupted and in future uncertain supply of natural gas rooted in regional crises and war in neighbouring countries, and global developments that make renewable power production technologies - in particular wind and solar - technically feasible and economically viable.

The economic potential for wind and solar based energy production are huge in Jordan compared to its energy demand. A transition to a renewables-based electricity system seems to be a promising perspective, although its realisation will not happen by itself, but requires central actors to set the course. These central actors are the current main regime actors which due to the centralised structure of the system have almost full control over the process.

We propose that given the current state of the niche and the timing and nature of the interactions of regime and niche levels a transformation pathway seems a likely and plausible future development. We suggest that options to prolong natural gas based electricity production that are available in the short and mid-term can be used to bridge the time until the required experimentation and learning with RE has taken place and a RE-based electricity system, including production and grid capacity, is implemented.

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